Public Transport Companies Environmental Test Manual

Part 3 – heaters

PREPARED BY

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1. Introduction

For health and environmental reasons, the Public Transport ~~Companies~~ Authorities (PTA~~C~~s) have focus on decreasing emissions from their buses as much as possible.

The same goes for the heaters in the buses. To ensure the lowest possible emissions of CO and soot particles as well as to achieve the highest possible efficiency of the heaters, the heaters in buses used on the routes of the Public Transport Operators (PTOs)~~transport companies~~ are continuously controlled. The control is carried out as Environmental Test.

The Danish PTA~~C~~s' Environmental Test Manual is used to control if the heaters are well maintained and thus that the emissions are as low as possible. In addition, the Environmental Test ensures that PTOs comply with the requirements of the PTA~~C~~ concerned.

The manual describes the measurement requirements for controlling the heaters, and the manual can be used by the PTO for self-control or by a PTA~~C~~-approved measuring company for third-part control.

The manual has been prepared by the Danish Technological Institute at the request of Movia.

2. Emission and temperature measurements on bus heaters

2.1. Requirements for the measuring equipment

The measuring equipment must be portable, as the measurements are often performed at the PTOs' bus depot premises. Preparing the measuring equipment may take up to 60 minutes on the first bus, as the equipment needs to be warmed up and calibrated before the first measurement. Subsequent measurements can be done faster, typically between 30 and 45 minutes per measurement.

A complete measurement system shall consist of a gas analyzer, a soot number measuring instrument, temperature sensors, data loggers and a computer.

Gas analyzer

The gas analyzer must have a CO_2 measurement range of min. 0-18 vol% and a measuring solution of 0.1 vol% and a CO measurement range that does not exceed 0-5000 ppm with a measuring solution of 1 ppm.

The test report shall indicate the equipment used, including calibration equipment/gases.

Soot number

For measuring soot number, either a manual soot pump with paper strips or an electronic soot number measuring instrument is used.

If a manual soot pump is used, 10 pump strokes are taken from the raw exhaust gas. The exhaust gas is pulled through a paper strip and the soot number is read on a Bacharach scale from 0 to 9.

If an electronic soot number measuring instrument is used, the manufacturer's instructions must be followed.

Temperature sensors

Ambient temperature, flue gas temperature and coolant temperature (at the heater) shall be measured. Coolant temperature can be measured at the outside of the heater's coolant connection. Type K or equivalent temperature sensors must be used for temperature measurements.

2.2. Data collection requirements

The data from the gas and temperature measurements are read by the data collection system once per second. The data collection system must be able to store data from the full measurement cycle, and it must be possible to export data to a format that can be read by a regular PC (e.g. txt, csv, or the like).

2.3. Requirements for measurement companies / technicians

2.3.1 Requirements for measurement companies in the case of third part control

The measurements must be carried out by an independent measuring company approved by the PT~~C~~A for the purpose. A company for third party control shall not have any personal or financial interests in the outcome of the measurements. For example, the workshops normally used by PTOs will not initially be considered impartial.

2.3.2 Requirements for measurement technician

Documentation shall be provided to prove that the measurements performed are carried out by personnel with appropriate training, including knowledge of general measurement techniques, calibration, quality assurance and reproducibility of measurements.

2.4. Maintenance and calibration

2.4.1 Gas measurements

The instrument for measuring CO and CO_2 shall be arranged so it is possible to check the equipment at the measurement site with a test gas. The measuring instrument shall be maintained and calibrated in accordance with the applicable manufacturer's recommendations.

2.4.2 Data collection

The data collection system shall collect data while the measuring instruments are calibrated. The data collection system is maintained according to the applicable manufacturer's recommendations.

2.5. **Preparing for measurement**

Before measurement, it must be ensured that the heater does not have defects or shortcomings causing the heater to not function normally. There must be no visible defects around the heater or significant waste of fuel or coolant.

Before starting the measurement, check that the bus does not have alarms on the instrument panel related to the heater.

The measurement may be carried out on a hot or cold heater. Before measurements can be considered applicable, the heater must run at least 6 minutes.

It shall be indicated on a measurement chart whether the heater was at operating temperature before the measurement. This is done to avoid questions of doubt regarding compliance with limit values.

The flap to the heater room shall be closed during the measurement unless access is made through the engine compartment.

2.6. **Preparation measuring equipment**

Before measuring, the gas analyzer is calibrated and checked for leakage. Calibration data is logged, and it is noted in the measurement chart that leakage has been checked.

When the equipment is ready, the tip of the measuring probe and thermoelement for exhaust gas temperature measurement is placed about 50 mm inside the exhaust pipe – as a starting point in the center of the pipe mouth. The pipe mouths can have many shapes, so it can be difficult to place the probes precisely in the center, but this is done to the extent possible. It is recommended to take a photo of the installation.

Due to the compact construction of the heaters, there is a relatively short way from the combustion zone to the mouth of the exhaust pipe, and there is a risk that the flue gas is not fully mixed up at the mouth. Thus, there may be examples of higher CO_2 elsewhere than in the center.

If the measurement must be performed anywhere else than at the pipe center, it is the PTO's responsibility to inform the measurement technician accordingly.

If it is not possible to measure 50 mm inside the exhaust pipe, it is to be noted in the measurement report.

2.7. **Measurement procedure**

The measurement is carried out at the PTO's bus depot premises with the engine idle or with a charger connected to the battery. Where a charger is used, it should be ensured that the voltage on the heater is sufficient and at least at the level required by the manufacturer of the heater.

Measured parameters

- CO and CO_2
- Soot number (does not apply to CNG heaters)
- Exhaust gas temperature, coolant temperature and ambient temperature
- Voltage if the measurement is done with charger connected.

Requirements for

- CO_2
- CO average and CO max.
- Exhaust gas temperature
- Soot number (does not apply to CNG heaters).

A total of four ignition periods are run through, and the heater is switched on and off manually for each run.

The first ignition period counts as pre-heating, while the last three are valid. To remove the heat produced, the thermostat in the bus is set to maximum heat, the cabin blowers are turned up and the doors are opened. If necessary, the bus engine flap may also be opened for cooling.

Before each ignition, it is assessed whether the temperature of the coolant is sufficiently low to allow the measurement to be carried out without the water becoming so hot that the thermostat will switch off the heater. Usually this happens at a coolant temperature around 60-70°C. If the coolant is assessed too hot, ignition must wait until the temperature is assessed sufficiently low.

Once the temperature is in place, the heater can be turned on.

During each ignition period, the heater runs up to 6 minutes or until CO and flue gas temperature over the last 20 seconds have not clearly changed more than 1%. Soot shall be sampled in the last minute of the measurement (not applicable to CNG heaters). The heater is then switched off and the procedure is repeated until three applicable ignition periods have been run through.

Measurement data for the last 20 seconds of each ignition period shall be averaged regarding CO and CO_2. Maximum exhaust gas temperature and maximum CO are determined for the entire ignition period.

2.7.1 Criteria for approvement

The following must be met for the heater to be approved:

1. At least two of the three measurements comply with the requirements
2. The average of the three measurements shall comply with the requirements
3. Measurements must be performed immediately in succession

If it is estimated that the measured values are abnormally low/high because of defects, the PTAC may require the heater to undergo a further Environmental Test once these defects have been rectified.

It is recommended, but not required, that the measurements are carried out at an ambient temperature below 20ºC, as higher ambient temperatures can cause challenges in terms of drawing heat from the heater.

If it is not possible to complete the three measurements due to the way the ECU of the bus controls the heater, or other things not directly related to the heater, the measurement is carried out in the best possible way, and the measurement technician notes the reason for the deviation.

2.8. **Limit values**

The following limit values shall apply:

Table 1. Limit values. The emission limit values are indicated based on wet/raw flue gas.

Parameter	Limit
CO_2	> 9%
CO (average)	< 300 ppm
CO (max.)	< 1500 ppm
Exhaust gas temperature (max.)	< 350 ºC
Soot number (not applicable to CNG heaters)	< 1 Bacharach

2.9. Quality assurance

The measuring company shall be able to document the result (as well as raw data) of the field calibration, provided that the PTAC requests it.

3. Report and documentation

Measurement results must be entered in a document which, together with measurement charts, etc., is placed in an electronic database to which the PTAC has access.

The electronic versions of the measurements, including raw data, shall contain a time and date code which is automatically generated by the computer/data collection system. The following shall be stated in the documentation for each measurement:

Measured concentrations of CO_2 and CO, soot number values, ambient and flue gas temperatures, measuring site, heater manufacturer, heater model, heater heat output, bus number and which measurement technician/measuring company has carried out the measurements.

Naming files and data setup in the file (e.g. the order of the individual columns of data) are agreed separately with the PTAC.

In addition, the measuring company concerned shall ensure that the following information is stored:

- Results from continuous calibration/adjustment of the measuring equipment
- Information on defects and repairs of measuring equipment relevant to the implementation of correct measurements.

The results of the Environmental Test are the property of the PTAC and may not be published or used by PTOs' or the measuring company in any other context without the PTA'Cs' permission.

3.1. Cases of disagreements

In the event of a reasoned disagreement between the PTO and the measuring company, the PTAC is the supreme authority. The PTAC may require documentation of the calibration interval and calibration protocol from the company performing the measurements.

Appendix A – Test report

Date, start time (yyyy-mm-dd hh:mm):	
Date, stop time (yyyy-mm-dd hh:mm):	
Site for measurement:	
Bus manufacturer:	
Bus model:	
Bus number:	
Bus registration number:	
Bus Euro norm:	
Heater manufacturer:	
Heater model:	
Heater heat output:	
PTO:	
PTO's bus depot premises:	
Method (Environmental Test Manual, version):	
Ordered by:	
Measurement performed by:	

Measurement equipment

Id	Type	Model	Range

Measurement results

	Meas. 1	Meas. 2	Meas. 3	Avg.	Limit value	Passed / not passed
CO_2						
CO (average)						
CO (max.)						
Exhaust gas temp.						
Soot number (not applicable to CNG heaters)						

Remark

Conclusion

Pass/fail: